

## Optimization to minimize the longitudinal emittance $\varepsilon_z$ at the AWA facility

This report deals with the minimization of the longitudinal emittance  $\varepsilon_z$  at the AWA facility. In previous simulations performed with Astra, it was shown that a way of minimizing  $\varepsilon_z$  consists in lowering the photocathode drive-laser pulse length. Usually, the laser pulse duration is 3.5 ps, but it can, in principle, be lowered to 0.4 ps.

### I. OPTIMIZATION IN ASTRA

A first set of optimization was done with Astra for an initial distribution which was transversely uniform and with a Gaussian temporal distribution. The distribution was cylindrical-symmetric. Using `sddsoptimize` the longitudinal emittance was minimized at  $z = 3.56$  m from the photocathode, i.e. the position of YAG3. This location is close to the tap-off point for the emittance exchange dogleg. The variables used in the optimization were:

1. The photocathode drive laser beam size on the photocathode  $\sigma_x$ .
2. The laser pulse length  $\sigma_t$ .
3. The launch phase of the rf gun  $\phi$ .
4. The electric field of the rf gun  $E_1$ .
5. The maximum values for the magnetic field associated to the three solenoids  $B_{bucking}$ ,  $B_{focusing}$ , and  $B_{secondary}$ .

The electric field of the linac and the bunch charge were set to respectively  $E_2 = 16$  MV/m and  $Q = 100$  pC. Finally the magnetic field strength for the bucking and the focusing solenoid were constrained such that  $B_{bucking} = -B_{focusing}$ . The optimizations were performed using Astra and the optimized values found were subsequently used as input parameters for more detailed simulations in Impact-T (a 3D simulation code). Table I gathers the optimum parameters that minimize the longitudinal emittance to approximately  $4\mu\text{m}$ .

TABLE I: Optimized values for the AWA facility at  $z = 3.56$  m using Astra

Symbol	Value	Unit
$E_1$	37	MV/m
$\phi_{gun}$	81	rf degrees
$B_{bucking}$	4.106e-2	T
$B_{primary}$	-4.106e-2	T
$B_{secondary}$	-5.43e-2	T
$\sigma_x$	2	mm
$\sigma_t$	0.616	ps
$(\varepsilon_x, \varepsilon_y, \varepsilon_z)$	(9,9,4)	$\mu\text{m}$

Figure 1 compared beam parameters evolution along the beamline obtained from Astra and ImpactT simulations for the optimized parameters devised with Astra. The emittances  $(\varepsilon_x, \varepsilon_y, \varepsilon_z)$  values at 3.56 m

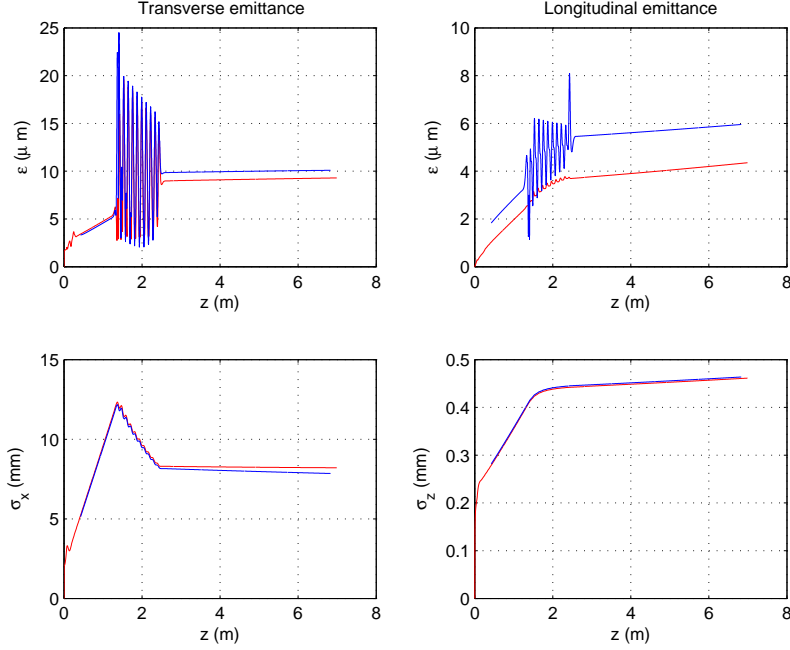


FIG. 1: Astra (red line) Vs ImpactT (blue line) for the optimum settings predicted by Astra .

are (9,9,4) in Astra compares to (9.8,9.8,5.5) in ImpactT.

Figure 2 presents the transverse trace spaces  $xx'$  and  $yy'$  at  $z = 3.56$  m associated to the Astra simulations.

## II. OPTIMIZATION IN IMPACTT

The second set of optimization was done in ImpactT. In ImpactT, the initial distribution was fixed and only the gun parameters and solenoids were varied during the optimization. The rms laser beam size was taken to  $\sigma_x = 2$  mm and the laser pulse length  $\sigma_t = 616$  fs. Specifically we varied the following parameters to minimize the longitudinal emittance:

1. The launch phase of the rf gun  $\phi$ .
2. The electric field of the rf gun  $E_1$ .
3. The maximum values for the magnetic field associated to the three solenoids  $B_{bucking}$ ,  $B_{focusing}$ , and  $B_{secondary}$ .

This time we did not impose the constraint  $B_{bucking} = -B_{focusing}$ . The optimize parameters that minimize the longitudinal emittance at  $z = 3.56$  m are shown in table II

Figure 3 compares Astra and ImpactT simulations for the optimized parameters done in ImpactT. The match here is perfect very good.

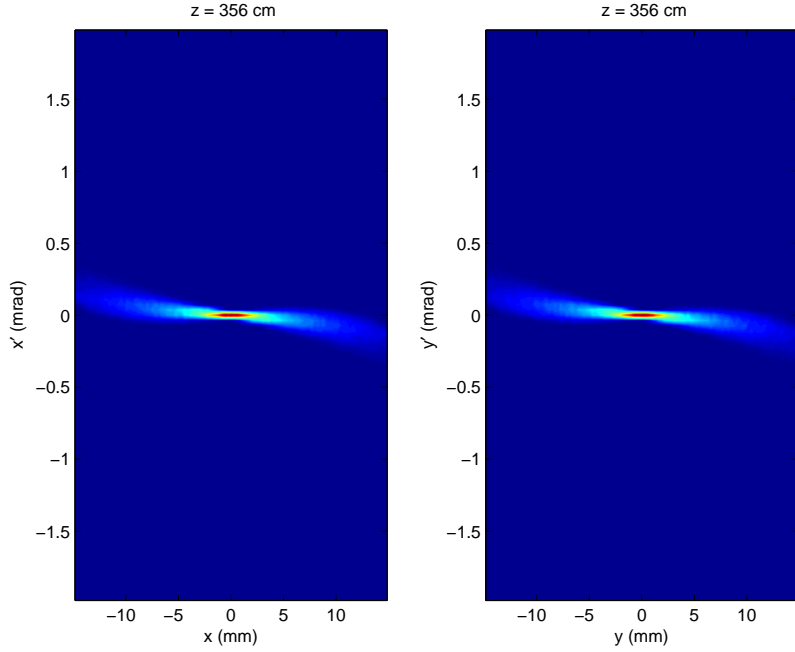


FIG. 2: Transverse trace space of the bunch at  $z = 3.56$  cm for the Astra optimization.

TABLE II: Optimized values for the AWA facility at  $z = 3.56$  m using ImpactT

Symbol	Value	Unit
$E_1$	25.3	MV/m
$\phi_{gun}$	50	rf degrees
$B_{bucking}$	0.1187	T
$B_{primary}$	-0.139	T
$B_{secondary}$	-0.0033	T
$(\varepsilon_x, \varepsilon_y, \varepsilon_z)$	(17,17,5)	$\mu\text{m}$

Figure 4 present the transverse phase space  $xx'$  and  $yy'$  at  $z = 3.56$  m.

In this set of simulations we noticed from the transverse phase space that there is a large  $x - y$  coupling coming from a non-vanishing magnetic field on the photocathode. Interestingly this has application to generate a flat beam. From the angular momentum computed from the particle distribution we for-see the emittance of this magnetized beam  $(\varepsilon_x, \varepsilon_y, \varepsilon_z) = (17, 17, 5)$  to possibly be transformed to  $(34, 0.2, 5)$ , i.e. a flat beam with a transverse emittance ratio of  $\varepsilon_x/\varepsilon_y = 210!$

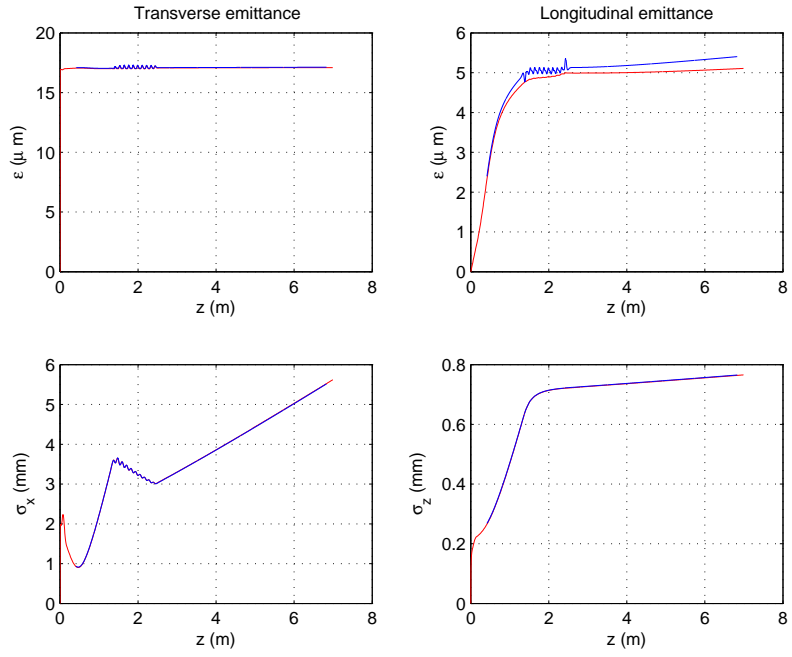


FIG. 3: Astra (red line) vs ImpactT (blue line) for the optimization predicted by ImpactT .

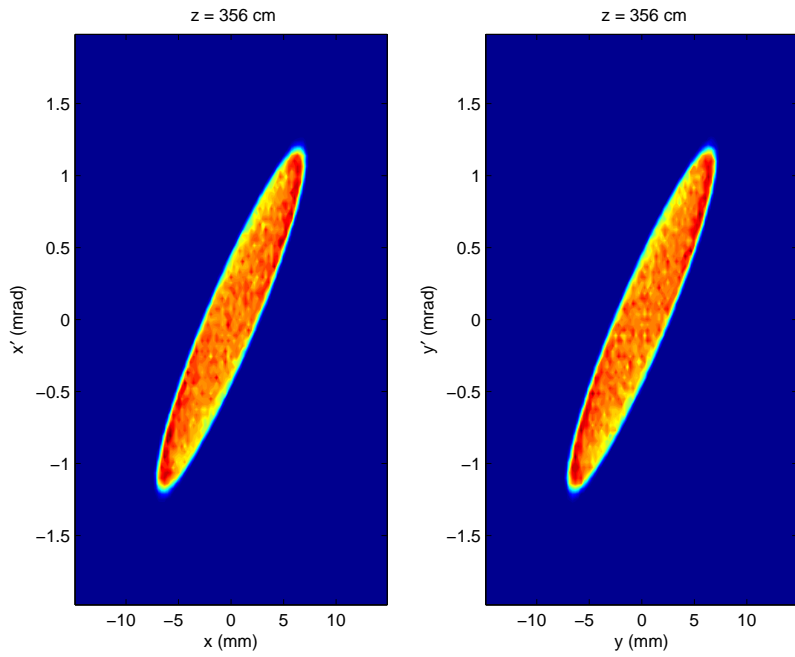


FIG. 4: Transverse Phase space of the bunch at  $z = 3.56$  m for the ImpactT optimization